same web server used to advertise new movies. Thus, the data shown in figure 2 may overstate website growth.

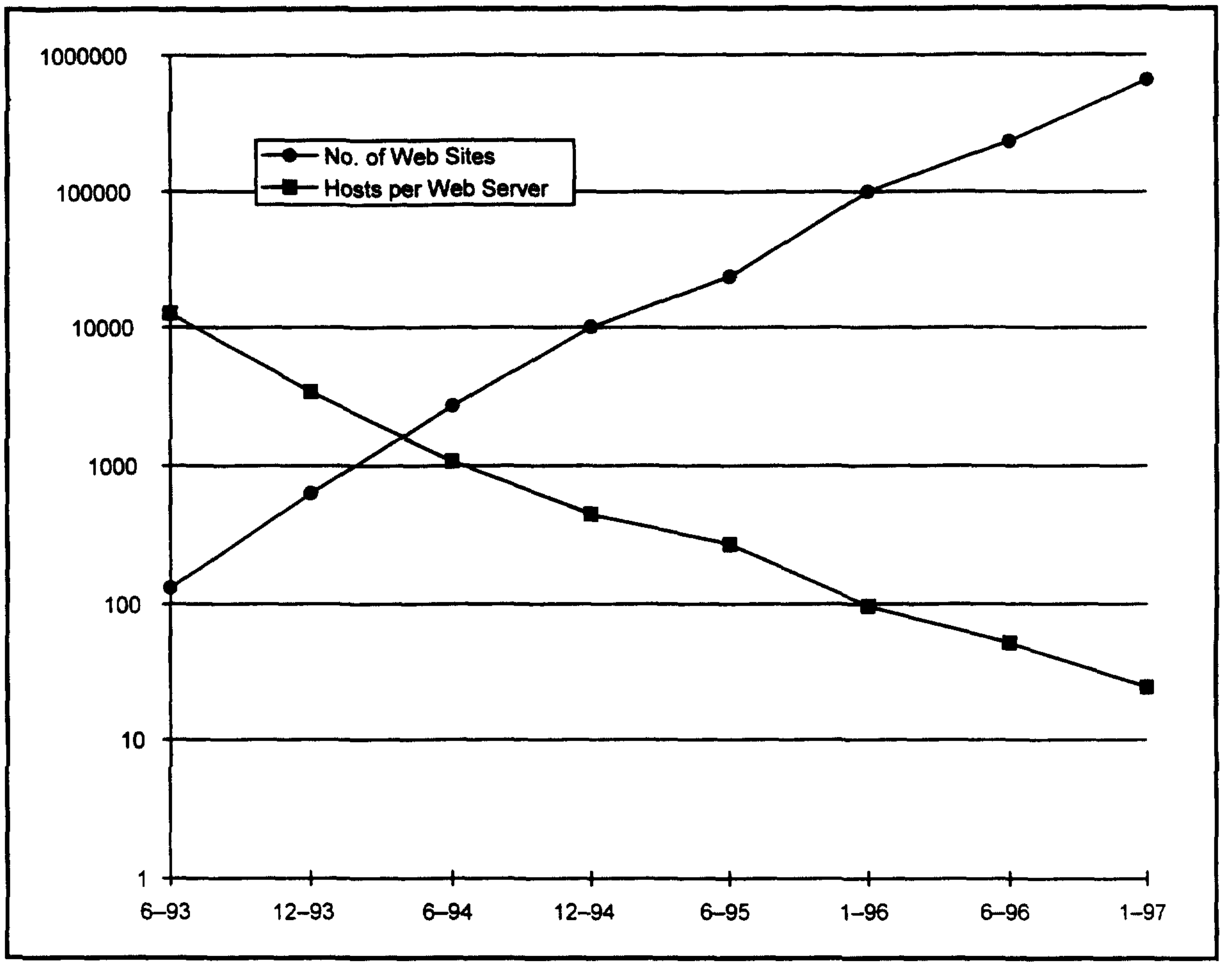

FIGURE 2: Website Growth and Hosts per Web Server

Residential Online Users of the Internet

It is clear that the Internet itself is growing exponentially, but what about its users—the primary measure of interest in any market study such as this? Here, the evidence appears to indicate that the user population, at least in the U.S., is growing very rapidly, but more linearly than exponentially—i.e., with a diminishing growth rate over time.

Market Size and Growth

For the U.S. as a whole in mid-1996, approximately[6]:

- 195 million adults are at least 18 years old. Of these:
- 73 million (37.2%) use home PCs
- 33.7 million (17.2%) use the Internet—at work or home or both
- 24.3 million do so at least once per week:
  - 43% or 10.4 million at home, exclusively
  - 21.3% or 5.2 million at work, exclusively
  - 35.7% or 8.7 million at home and at work.
- Thus, 19-20 million adults are active residential users of the Internet—about 78.7% of the 24.3 million that use the Internet at least once per week.
- During the past 2-3 years, there has been a major shift toward home access—from 42% in 1994 to the 78.7% figure quoted above for 1996. This big increase is primarily the result of AOL and CompuServe offering Internet access. Such major online services now provide access for over 40% of all Internet users.
- However a new trend is emerging: increasing numbers of Internet users are now moving from the major online services to commercial Internet service providers (ISPs)—often to the newer, well-financed ISPs of firms such as AT&T, MicroSoft, BBN, and the LECs. SRI expects this migration to intensify over the next several years.

Market Segments

Higher education levels and upscale household incomes characterize the 33.7 million adults in the U.S. who were using the Internet in mid-1996[7].

- More than 75% of Internet users have attended college—compared to only 46% of the general population. A high level of education is the single, most defining demographic determinant of who is on the Internet today.
- More than 65% of Internet users have household incomes of $50,000 or more—compared to only 35% of the U.S. population as a whole.

However, survey results in 1996 and 1997 suggest that the Internet is increasingly attracting mainstream consumers, such as older, less educated people and households with less than $50,000 in annual income. These data apply to all types of usage—i.e., work/home/school.

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[6] "LeadingEdge 1996: Media Use Snapshot", SRIC Media Futures Program, November 1996

[7] "LeadingEdge 1996: Media Use Snapshot", SRIC Media Futures Program, November 1996

There are, of course, many other ways to characterize this market. For the purposes of developing the demand curves in this report, we can categorize the 20 million or so adults in the U.S. who are active residential online users of the Internet from home as follows.

- Telecommuters: about 25% of the users who work at home, are employees of companies that subsidize home access, and who access the Internet for business applications.
- Home businesses: some 30% of the users who operate a business out of their home (i.e., from their home office), and who access the Internet for business applications.
- Home applications: roughly 60% of the users who access the Internet for non-business applications.

These three market segments overlap somewhat; sizes are very approximate. Figure 3 illustrates these three segments, their relative sizes, and their overlap. Sizes and overlap are approximate.

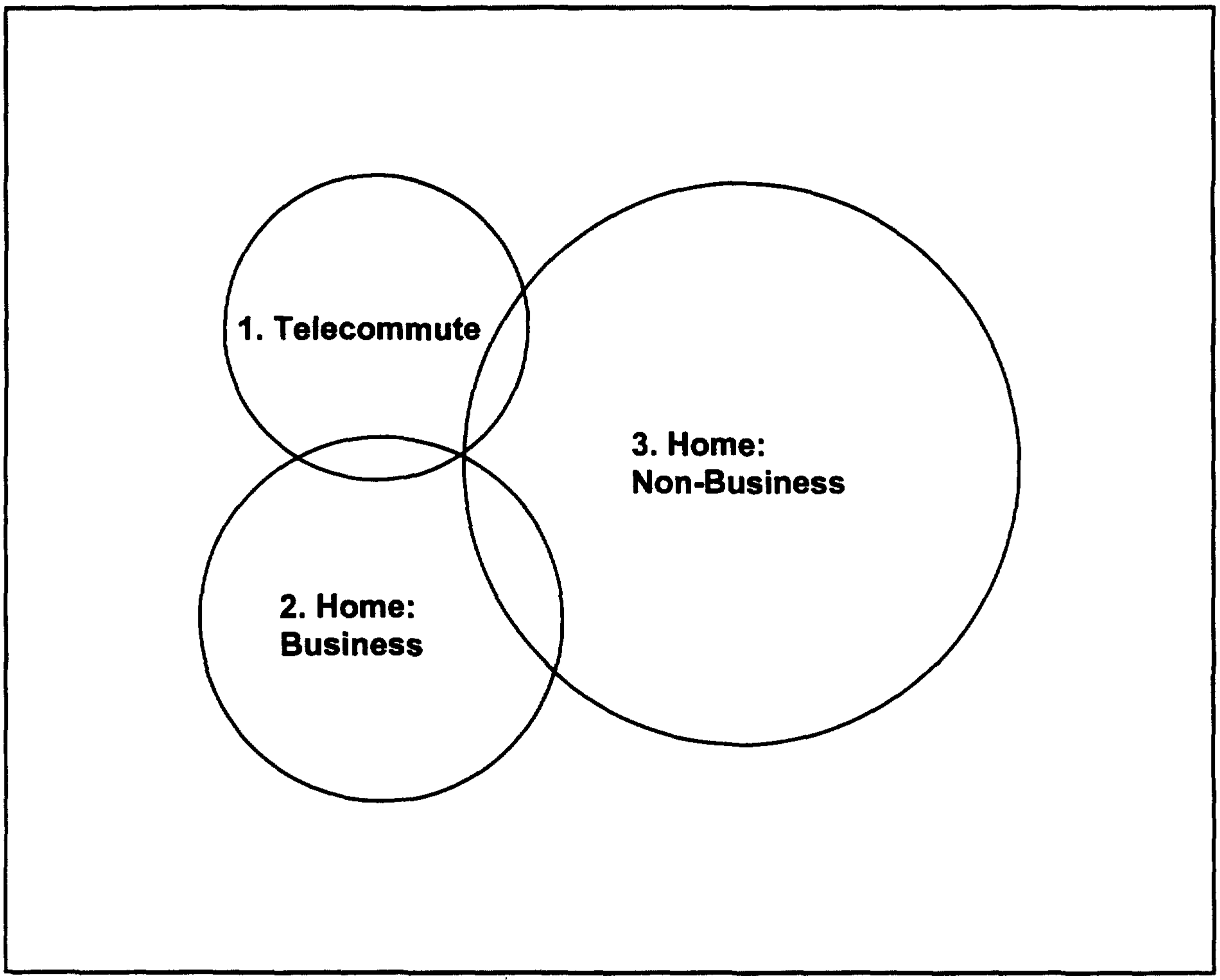

FIGURE 3: RESIDENTIAL MARKET SEGMENTS

Modem Speed

Some 39.2 million U.S. households had at least one home computer in 1996 (36.7 % of all households), and 31.6% of these, or 12.4 million households own at least one high-speed modem (14.4 kbps or higher)[8]. The breakdown by modem speed is detailed in Figure 4. Penetration of the higher-speed modems has been limited both by their availability (a supply-side constraint) and by their higher price (a demand-side consideration).

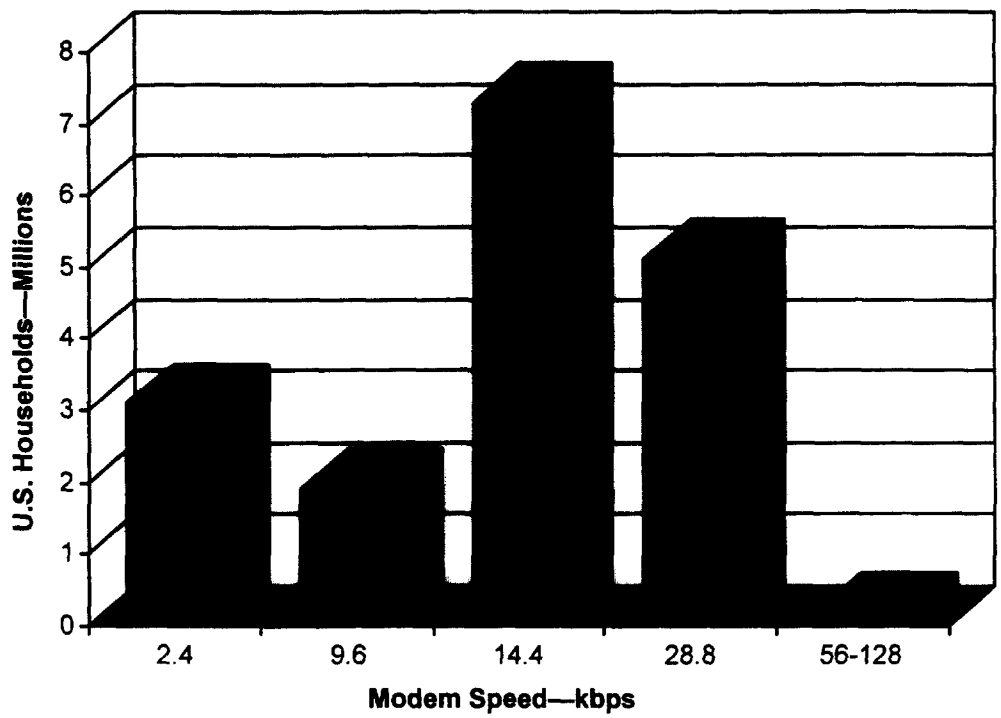

FIGURE 4: U.S. Households and Modem Speed

Inactive Users

A large number of potential users are inactive Internet participants. These include:

- Consumers who have a PC at home and have bought a modem, but have never connected it up
- Dropouts—former users who have tried the Internet at least once, but are now inactive.
- Low activity users—users that are access the internet less than once a week

Several recent surveys indicate that this "inactive factor" is substantial:

[8] "LeadingEdge 1996: Media Use Snapshot", SRIC Media Futures Program, November 1996

- The SRI 1996 survey showed 24.3 million out of 33.7 million used the internet at least once a week, an inactive factor of 9.4/33.7 = 28%
- According to Intelliquest, there were 56 million persons older than 16 in the U.S. in early 1997 that accessed the Internet at home/work/school. Of these, 10 million have very limited usage[9]. Thus, there are about 46 million active users, or an inactive factor of 10/56 = 18%.
- Of the 40.6 million adult users as reported by ETRG in early 1997, more than 9 million Americans have tried the Internet but have subsequently dropped out—i.e., an inactive factor of 9.3/40.6 = 23%. About 20 million of these users find the internet indispensable, the other half use Email only, or have limited usage[10].

In any case, such high rates of inactivity lead to high subscriber acquisition costs—a primary reason why profits have been so disappointing for major online vendors such as AOL. It is likely that many of these potential users "gave up" after experiencing poor performance or that the internet's content and format is not attractive to them.

Growth Problems

The rapid growth in Internet users, sites and traffic described above—really more of a sudden flood than a predictable increase—has stressed the existing telecom infrastructure beyond its capabilities to accommodate change and has caught planners off-guard. This has led to congestion and poor performance, both of telco plant and ISP plant. A dramatic example of such growing pains is AOL's recent overload brought on by its fixed-price announcement, targeted for the mass market.

Congestion Problems

In brief:

- Home use growth is causing major problems for the LECs (larger holding times than voice calls, switch congestion, loss of revenues). While this is perhaps more of a problem for POTS (voice) than for Internet access, a more responsive setup such as a separate data network that doesn't interfere with standard POTS service at the central office would clearly improve the quality of both services—e.g., by reducing the occurrence of busy signals or no dial tone.
- Congestion in the local switches and in the lines to the ISP continues to get worse. The lines to the ISP are especially vulnerable to high levels of concentration. Again, the solution appears to be data network bypass and a more packet-oriented approach to the data to take better advantage of its bursty nature.

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9 1997 American Internet User Survey by FIND/SVP: http://etrg.findsvp.com/internet/findf.html, see also URL group 3

10 1997 American Internet User Survey by FIND/SVP: http://etrg.findsvp.com//sb/sbbrochure.html, see also URL group 3

- Access line speed is an perceivable bottleneck to the user, but only one of several. Other critical constrictions include the sizing of ISP facilities and the problem of long holding times "nailing up" the user-ISP connection. In fact, higher line speeds could make things worse in other ways—e.g., by increasing user acceptance, usage, and (thus) creating longer holding times.
- Long holding times are the result of data modem calls tying up a line from the user, through the switch(es), and to the ISP. As noted, increasing the datarate at the user and ISP ends of the line may actually increase holding times. New digital technologies like ISDN (which has lower call setup times) can alleviate this problem when used with transport protocols (for example, PPP[11]) that allow the call to be terminated after a user-definable idle time. The bursty nature of internet access (access a web page then read a while) should yield shorter holding times. Note that the minimum call billing time is a factor in this, and is under the control of the LECs.
- Another user characteristic leads to additional congestion—as users move to higher rate modems, their session times increase because they are more satisfied, and hence access more information. Intelliquest has estimated that the average time spent online has increased from 6.9 hours per week in Q2 1996 to 9.8 hours per week in Q3 1997.

Considerable discussion has been given to congestion buildup because of the wide use of modem access to ISPs. Reports on studies are available from PacTel, Bell Atlantic, and several other RBOCs/LECs[12].

Performance Problems

Home users of the Internet are dissatisfied with poor quality of service (QoS). Long delays (latency), dropouts, and increasing busy tones when trying to access the Internet are the primary complaints.

Fully 65% of the 33.7 million adult Internet users in the U.S. are frustrated with their slow online connection. This frustration is strong irrespective of how often the user accesses the Internet.

Moreover, 45% of current Internet users say that they would explore the Web more if it didn't make them wait so much. So, higher demand will be additional online time per user in addition to larger number of users[13].

Users care especially about:

- The time it takes to download: latency is generally perceived as more important than bandwidth in this regard.
- Reliability. Factors include:

[11] PPP is a serial line protocol, see Appendix 1–Glossary for full definitions
[12] Pacific Telesis Group paper: *Surfing the Second Wave*, March 1997 http://www.pactel.com/about/mgnt_perspectives/fitz102396.html, see also URL group 2
[13] "Leading Edge 1996: Media Use Snapshot", SRIC Media Futures Program, November 1996

- physical path redundancy
- forward error correction
- bandwidth reservation
- provisioning "headroom",
- probability of successfully getting a response (e.g., dialtone/PPP)

For real-time interactive communication (e.g., isochronous traffic such as voice), delay and delay variance are also critically important measures—e.g., maximum delay jitter of 100 ms.

See Appendix 2 for a more detailed discussion of service quality.

Slow Access is a Secondary By-product of Line Speed

Access line speed is but one of many aspects that affect delays, and a secondary aspect at that. As discussed earlier:

- Internet bottlenecks can occur anywhere—e.g., at the ISP site, the backbone net, the access line or the user location—and at any time. Supplying all users with a perfect access line of infinite bandwidth would still not guarantee better service quality. Higher access line speed is therefore a necessary, but not a sufficient condition for better quality as perceived by the end user.
- While line speed is a direct, technical measure of supply-side capability, it is an indirect, derived measure of demand-side value from the point of view of the customer.
- What users notice is delay (latency); and lower overall latency is a secondary benefit of higher access bandwidth. Higher bandwidth local access will make delays in ISP switching, server response and client applications (i.e., browsers) much more apparent, and hence the focus of improvements. It should be noted that the current nature of the service provided by ISPs might have to change in order to address these issues.
- latency for current net traffic is primarily one-way—inbound to the user (outbound from the ISP and CO switch). Cable modems and satellite downlinks (e.g., DirecPC) are competitors to xDSL now for this type of traffic, but new traffic types will require low latency in *both* directions.
- The downside of "45% say they would explore the web more if they didn't have to wait so much". is that increased usage (online time) will have an adverse effect on holding times, so more must be done than simply improve line speeds. New networking strategies are needed that better match data traffic patterns. Some potential solutions:
  - separate voice and data networks/switches)
  - D-SLAMs (Digital Serial Line Asynchronous Multiplexors); non-blocking line multiplexors
  - high-bandwidth xDSL modems residing in the LEC Central Office.

Using line speed (e.g., in kHz) to measure Internet performance is analogous in many respects to using processor speed (e.g., in MHz) to measure PC performance. Advertising can sensitize the market to accept these measures, and consumers may be willing to pay more for "more MHz", but actual performance will depend on a number of other metrics as well.

The LEC Opportunity

The growing pains discussed above constitute a major opportunity for LECs to capture market share by offering more acceptable, higher quality access services to home Internet users. In particular, to sustain current market growth, there is a need to:

- provide better performance as perceived by users
- relieve the bottlenecks, including the access links
  - user access: links from user to the LEC Central Office
  - ISP access: links from the ISP to the LEC Central Office

Perhaps more importantly, higher quality access can attract additional market segments and stimulate new applications, including:

- Disappointed former users (the inactivity factor)
- Emerging market segments (novices; teens; lower income users)
- Future services, including interactive applications (games; collaborative; Internet telephone).

The local telcos are ideally positioned and suited to provide solutions, given their experience with the mass residential market, their expertise in providing real-time interactive communications services such as telephony, and their existing connections to the home.

Given the uncertainties of Internet evolution, the best strategies will be flexible ones.

Size and Growth of Home Internet Access Market

Current Outlook

Some data on internet user growth trends are presented here. There are three types of consumers involved:

- Active users—people who tend to go online to use the net frequently (i.e., at least once a week). This group provides the most predictable basis for developing forecasts.
- Inactive—the "tried it once or thought about it, but didn't like it" group. This group's willingness to use the network is not necessarily based on price. As such, its size and growth are more unpredictable.

- Wait and See—the majority of the population that hasn't bought a home computer, either for economic reasons or because they don't see any benefit of computing in their personal or business lives. Marketing high speed Internet access to this group will be an "uphill battle"—at least during the time frame considered in this report. The network computer (NC) has been widely touted as bringing this group into the computer-literate camp, and hence, the scenario analysis in the next section will consider this potential segment.

Thus, the first group (active users) is the primary target set of customers for higher speed access capabilities. This group is composed of (some overlap):

1) Telecommuters—people who work in an office, but who additionally do work at home. Their company pays for the home access line and equipment.
2) Home business users—The business pays for the home access phone line and equipment (e.g., modems).
3) Home non-business use—The home access line and equipment come out of the household budget.

SRI International's proprietary Values and Lifestyles (VALS ™) consumer segmentation focuses on adult consumers' motivations for buying products, the media they use, and the activities they engage in. On the basis of consumers' fundamental attitude and lifestyle orientations, VALS divides the adult U.S. population into eight psychographic segments of roughly similar size. See Appendix 3 for further detail on these types and their definitions.

In order to account for the two types of user demand—increase in online time and increase in number of subscribers—we will only count active users that log on more than once a week. Other, occasional users are considered part of the inactive group. If new conditions such as higher bandwidth local access increase their online time, then they are counted as a new active user. There will likely be an overall increase in online time, even for active users. For the purposes of this study, we will account for this by determining an average online time per active user and then look at how that average changes over time.

As detailed in table 1, consumer acceptance of the Internet varies widely, depending on the segment of interest[14]. Each type of user has different reasons for using the Net; and each segment responds to it in different ways. The last column, active home users, is the breakdown of the predictable group shown in Figure 3.

[14] 1996 VALS study & "Making Sense of Internet Statistics", David M. Rader, SRIC BIP Report # D97-2064, 1997

Group	Adults (Million)	Internet Users (work or home)	% Penetration	Active Home- Users (Million)
Actualizers	23.46	10.09	43	5.72
Achievers	27.37	6.84	25	3.88
Fulfilleds	19.55	4.69	24	2.66
Strivers	24.24	3.64	15	2.06
Experiencers	25.42	4.32	17	2.45
Makers	24.24	3.15	13	1.79
Believers	31.28	1.25	4	0.71
Strugglers	19.55	0.20	1	0.11
Total	195.11	34.18	17	19.37

Table 1 - ACTIVE HOME USERS FOR EACH VALS SEGMENT

In brief, research conducted by SRI's VALS program indicates that 65% of active home internet users are:

- *Actualizers* are classic early adopters who are inclined to incorporate new technologies into their busy lifestyles. They like the wide array of information on the Internet and its ability to help them stay in contact with their often far-flung social networks.
- *Achievers* have the second largest presence on the Internet, but they are the least intensive users, averaging three or fewer visits per week. Career oriented, these users tend to seek specific information or contacts that will help their career. They are less likely to surf the Web for fun.
- *Fulfilleds* act on "the need to know", and the information-intensive Internet is seductive to them. They are intensive users, on average logging on four or more times per week. Yet only half as many are on the Internet as are Actualizers. The reason may be that the Internet, still untamed and disorganized in its infancy, frustrates this group's sense of order and desire for predictability.

The middle two segments use the internet in the same proportion (23%) as their percentage of the total population (25.4%):

- *Experiencers* are often early adopters of technology, but they gravitate to it for stimulation and thrills. Although the Web offers interactivity, the content is often boring to this type of user. Greater intensity of sight and sound could attract more Experiencers and increase their frequency of use. Some 70% of them are now infrequent users.
- *Strivers* have little discretionary income, but are image conscious, so they follow the trends.

Other groups are either absent from the Internet or their representation is not in proportion to their share of the population (12% vs. 38.4%).

- *Believers* balk at the PC interface and therefore are largely absent from the Internet. In addition, the Internet so far lacks content and formats that fit with their traditional, family, and church-oriented lifestyles.
- *Makers* do not find that the internet provides enough practical value or the type of personal leisure activities they desire.
- *Strugglers* have minimal resources and can't justify the cost.

Future Growth factors

As developed above the predictable growth factors are:

- Each segment will grow somewhat in size (population growth)
- Home use will increase still further, as a proportion of home/work/school use. Part of this will be fueled by generation shift (kids begin using computers)
- Penetration will increase for each segment:
  - More computer awareness in schools and businesses
  - Novices, lower income will begin finding affordable computers
- Website hardware will get cheaper, smaller. Thus, more home users may be setting up their own web servers. These will require 24-hour "up all the time" symmetric access.

We assume here that the high-speed link is part of an associated data network that eliminates all remaining bottlenecks to improved service quality as perceived by users. If the new high-speed link is a one-time improvement (say, ADSL frozen at 1.1 Mbps), it will produce one-time surge in demand, but otherwise leave the underlying rate of growth unchanged. Saturation levels would also probably remain unchanged. The reason is that this year's innovation (1.1 Mbps) will be perceived as a commonplace "given" 3 years from now—the way 28.8 kbps is perceived today. It is very unlikely that development will remain frozen since 6 mbps xDSL modems exist today, but are pricey. However, some people will purchase the first generation products and hold on to them longer than three years..

If, on the other hand, innovation continues, (e.g., second generation xDSL at 6 Mbps within three years), then the rate of growth is likely to increase, as will ultimate saturation levels.

EMERGING INTERNET AND COMPUTER TECHNOLOGIES

Different Types of Internet Access Traffic

Internet traffic has increased and changed in character over the past ten years, transitioning from FTP (file transfer) and telnet (remote logins) traffic to Email and chatrooms (interactive bi-directional text streams) and finally to web browsing. The result is many different traffic types need to be supported over a packet switching network. Many studies have shown that throughput is optimized for such networks when packet sizes and traffic offering rates are very similar. Even though this is not the case, the transport and application level protocols (e.g., TCP/IP and telnet) have been modified and refined to closely approximate optimal performance for the primary traffic types listed below:

- Bursty two-way (Email)
- Continuous in bursts one-way (FTP, netnews, web access, streaming)
- Low volume commands one way and large bursts in the other (Web browsing, remote X-servers, telnet)
- Low volume two way (text) traffic (chat rooms, text conferencing)

A new traffic type is occurring more often on the internet which has significantly different characteristics and stresses the fundamental premises of packet switched networks. Isochronous (continuous in bursts, two way) traffic like voice of video conferences are becoming more popular and are not suitable for the large packet sizes and best efforts delivery of the current net. Other applications with similar traffic characteristics (games, synchronous collaboration) are poised to become significant network applications[15].

Low latency interactive network services have enormous market appeal. As an example, consider that the ARPAnet (the predecessor of the internet first operational in 1971) was commissioned by ARPA to allow contractors to share expensive computing resources. While the technology that was needed (remote computer access) was challenging, it did not take off (even in the research community) until a couple of frustrated system administrators created the first, crude, electronic mail system to communicate. Email was the primary appeal of early networking. The users really wanted inter-personal communications on a nation-wide basis, not just resource sharing. Similarly, as the ARPAnet evolved into the internet , usenet and the newsgroups became the largest source of traffic. When the internet moved from support from the U.S. government to commercial enterprises, chat rooms (again, interpersonal communications) became the big draw. Over one third of AOL's traffic is text chat support. It is no wonder there is a lot of interest in internet voice services!

So a large factor in creating user demand is inter-personal communications, possibly more so than information distribution—the primary service offered by web browsing. While the current internet web structure with many servers does provide a wealth of information, the slowness of response often defeats all but the most persistent user. Interactivity (low latency) is needed to support bi-directional communications. Note also that low latency is not just a network issue (higher bandwidths), but a systemic issue. Is the server you are accessing overloaded? Is your client browser running on a hardware base suitable for the CGI streaming you are requesting? Have you set up your system parameters correctly to make the most efficient use of compression options?

There are two types of trends in increased Internet traffic of interest in this study:

[15] *http://www.jup.com/newsletter/games/features/9801.shtml* , see also URL group 4

- Relatively predictable trends—e.g., the desire of current active modem users to want higher bandwidths for the current mix of Email, web-browsing and interactive text. This trend will be modulated by the emergence of smaller and cheaper websites at small businesses and households, leading to more outgoing traffic (and thus more symmetry re outgoing/incoming) and longer internet session times at household sites.
- Relatively unpredictable trends such as the low latency interactive traffic discussed above.

Of the unpredictable trends, two appear to be critical determinants of long-term Internet evolution. We are naming these classes in terms of the major impact on the types of traffic they will introduce.

- Dynamic software downloading and its stimulation of still more downstream traffic. These are primarily user-server interactions (thin client, thick server) and thus, are predominately one-directional. Examples include:
  - Network Computers (NCs) with all software residing elsewhere. User-friendly interfaces (e.g., Web TV at home)
  - Applications composed of software components (e.g., Java applets) so that some portions of code (e.g., plugins) are loaded from a server when needed.
  - Internet radio—real-time as well as off-peak hours (download during the night and listened to at some other time)
- Interactivity and its requirement for low latency. These are primarily peer-to-peer (client-client) applications. Examples include:
  - Internet telephony
  - Real-time games
  - Multi-user interaction
  - Videoconferencing

There are many factors that contribute to each of these traffic classes. Some of the factors that could impact network traffic very little or a lot are discussed, relating these factors to the various VALS segments.

Network Computing

Network Computers (NCs) are being touted as the next killer product that will bring all the hold-outs into the computer-literate and internet conversant fold. The concept is simple; make a very inexpensive end-user device that relies on network servers for most of the processing and storage. For the expected NC user application— a web browser—this model of thin clients and thick servers is appropriate. As a result, considerably more network bandwidth will be needed, depending on the level of processing shift. If the NCs have full browsers, the traffic between client and server (user and ISP) would be the same as for current web browsing. However, as web browsers acquire more and more features which require more local memory, the complexity of the required end-device increases. The alternative is that most of the browser processing is done on the server and the end-device is a very simple I/O processor. Screen updates will likely generate network traffic in this case which will increase and change the nature of the bandwidth requirements. In current browsers, accessing web pages is bursty with some (reading) time between accesses. With the I/O only NC, reading can also generate network traffic which could create almost continuous downstream traffic.

It is likely that some NCs will have Java interpreters and thus, a compromise situation will exist between the two extremes described above. In this case, a low cost NC might have a Java runtime chip and some local cache memory. So, only the portions of a web browser currently needed can be downloaded. Network traffic would be like current web browsing plus some additional software downloading (see next section).

Major vendors (Sun, Oracle, Intel, MicroSoft, Apple,) are all coming out with NC products and related services. The uncertainty here is whether this will be another bust like the personal digital assistant (PDA) market or whether it really will capture the consumers' imagination. These (primarily) low-cost hardware solutions do not address many of the reasons people have for not getting on the internet (or even using stand-alone computers)—too complex to use and maintain, not sufficiently interesting content, working on the internet is not organized or secure—as identified in the VALS studies.. However, the NC, much like higher bandwidth access (clearly needed for the NC), could be a strong catalyst to solving these more systemic issues.

Software Components, Plugins

Current software application products like MicroSoft Office are being driven by market pressures to increase the number of features with every new release. While this may provide the right incentives for consumers to want to upgrade to the latest version, the downside is that application memory requirements are growing almost as fast as new hardware technologies bring the price of memory down. The end result is that consumers are becoming disenchanted with the rapid obsolescence of computer hardware and software.

Another technical approach is emerging that has implications on network traffic—software components and plugins. This approach is in contradistinction to large, monolithic applications that contain the full suite of features plus every possible conversion for other applications—both older versions and competitors' versions. Applications are composed of a number of components and so the user needs only to load those components for the immediate task. If you want to compose a document, there is no need to load the final document formatting component. If you are doing spell-checking, only load that code. Plugins allow the user to download special processing (e.g., format conversions, decompressors) as needed from network servers. Browsers are the primary applications using plugins today, but the concept can be applied to any network-oriented application.

Although stand-alone users can benefit from the use of components, they become especially attractive for network computers with limited local storage. Then, components allow the downloading of just the capabilities needed for the task at hand. The increased network bandwidth demands caused by this approach while unpredictable are clearly sizable (depends on how the applications are partitioned, how predictable are the set of capabilities the user needs, and many other factors).

Videoconferencing

One of the "new technologies" that has been promised over the longest period of time is video telephones or video teleconferencing (VTC)—first introduced at the World's Fair of 1939, and subsequently marketed by AT&T as Picturephone in the mid 1960s. The hope of reducing travel and other expenses associated with world-wide corporations and business associations has not overcome the technical, economic and social hurdles. There has been a recent surge in videoconferencing products because of lower end-user equipment and higher bandwidth long-distance lines, but many barriers still exist.

The primary barrier to the adoption of VTC is our acceptance level for video imagery is very high, conditioned by television that not only has high quality images but significant real-time editing and production. Think of the Sunday NFL games with many different camera views always in focus, and the large trailer for real-time selection of the proper camera choice, instant replay and other visual aids. Of course, the expense of this type of video broadcasting puts it out of reach for large scale VTC applications, but it still sets the acceptance standard we all use.

VTC over the Internet suffers additional bandwidth and latency problems that currently limit widespread acceptability, especially for two-way, real-time applications. Real-time VTC can be very effective. For example, a microwave-based system has been used successfully for distance learning between remote campuses in Washington State[16]. The success of this system is directly related to the number of cameras in each classroom (three), camera operators at each classroom, and high-quality, full duplex transmission between all sites. These factors are seldom found in the current internet videoconferencing applications. These limitations and the inflexibility (or difficulty) in controlling the camera's pan and zoom often reduce VTCs to looking at talking heads—a very wasteful use of bandwidth. In these cases, good quality audio conferencing and still-frame snapshots would convey as much information. The power of video will not be realized over the Internet until it can be transmitted at much higher quality, with multi-camera real-time switching capability.

Thus, we do not expect VTC to be a widely-accepted, heavily-used Internet application within the timeframe of this study—i.e., up to the year 2004.

Internet Telephony

Transmitting voice conversations over packet networks has received a large amount of attention lately. The first demonstrations of voice over IP was made in the late 70s, but the "best efforts" delivery philosophy of IP routing led to less than toll quality. The primary culprit for this reduced quality was the IP routers where congestion is dealt with by dropping packets. The low quality in the early experiments was primarily due to congestion in the long haul or backbone networks. Voice over medium loaded LANs (i.e., Ethernet) was much closer to toll quality. Voice over IP networks continued as a useful traffic generator source for researchers to use to stress their networks and experiment with late multi-cast conferences (video also filled this role of a stressful traffic type). However, the limited quality kept it out of the main stream.

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[16] "A Study of the Washington Higher Education Telecommunication System - WHETS" SRI report, February, 1990.

Recent developments have changed this picture. First, long-haul networks—including overseas links based on fiber—now cost less and are no longer the major congestion bottleneck. The source of congestion has shifted to the local internet access where packets are still dropped. The second factor is the exponential growth in ISPs and their larger role in the Internet architecture. The ESP (Enhanced Service Provider) exclusion that reduces the amount ISPs pay to LECs creates a favorable environment for investing in new IP voice solutions. There has been a groundswell of activity to develop Internet telephony (Itel) products that concentrate on user equipment and local access. The recent Networld - Interop Conference devoted 27 out of 32 sessions to this topic. Forecasts vary widely: Internet voice services are predicted by some to grow from a $1 billion market today to a $60 billion market by 2002, with up to 35% of all calls traveling over IP networks by that date. While SRI does not necessarily agree with these rather bold predictions, they do indicate that the impact of Itel could be significant.

These rather bold predictions need to be analyzed in order to understand their relationship to high bandwidth internet access to the home. First, the majority of initial Itel products are PBXs that will concentrate a business's voice traffic at one site and use high speed data links to similar PBXs at other sites. These networks can be completely within a company (intranets) even though they are using Internet (IP) technology. Current IP voice gateways claim to be able to interface with standard voice switches to route calls back into the POTS network. The External Service Provider (ESP) exclusion has no impact on these internal networks, since voice traffic need not go with other company traffic to ISPs for internet services. This exclusion lets ESPs pay LECs a much lower rate for local access than regular long distance carriers. The fallout of such developments for the home users we are concerned with is that voice IP technology will emerge to meet this business user market and some products will likely be targeted to ISPs providing service to home users. For example, a home user with one of the new ADSL modems have a port for an ordinary phone as well as their computer. If the other end of the line terminates in an ISP with good access to long haul lines, the voice stream can be transported without encountering many potential congestion points.

The second factor is the role of billing. One prediction is that ISPs cannot provide large scale voice service because the overhead of determining the amount of voice traffic.. The nature of IP routing (all the routing information is in each packet, not in the switches) means that each individual packet must be examined to determine traffic type and then, all voice packets must be tallied by individual user. All this bookkeeping and then, billing individuals could overwhelm the ISP servers and make the service unprofitable. On the other hand, if the current fixed monthly fee structure were maintained, the ISPs would only have to enforce a maximum traffic bound for each user, an easier traffic measure.

In summary, technology advances make Internet Telephony an attractive and growing market segment, initially for large businesses, but spreading into the ISP/home user market. The actual penetration is uncertain because of the many factors surrounding pricing (and costs) of this service and the downward price pressure on voice service. The standard qualities we have come to expect for voice service—reliability, low latency, high voice quality—are still the norm and are well understood by the LECs. Marrying their long experience in POTS with the new technologies driven by the Internet can be a growth area for the LECs.

Internet Radio

One traffic type that can be easily supported by the current Internet structure is taking broadcast radio from one locality and providing it to another locality. Persons on travel that want to listen to the home town sports broadcasts, or those that want to listen to the BBC are examples. This service, if offered, has the potential of greatly increasing (outbound to the users) traffic with little user action required. It is an example of several other similar services that can greatly increase congestion. There are other alternatives for some of these other services (e.g., video on demand), but the Internet seems a good match for relocating local radio broadcasts.

The growth of this service depends on many factors—who will provide (convert to IP streams) the Internet radio content? How will they be paid? Will the ISP servers be overwhelmed, and thus have no incentive to provide them? Will there be enough interest in this service? Therefore this is another service in the category of uncertain penetration in the next 5 to 7 years, but one that is definitely possible.

Real Time Games

Computer games are getting more sophisticated as new hardware (e.g., Intel's MMX Pentium chips) arrives in the marketplace and are eating into the stand-alone video game market. Graphics, animation and real video clips are becoming part of the genre. As the appetite for more varied content increases, fueled by the number of kids that are computer literate, network-based games are a natural next step. However, the low-latency, high bandwidth interactions that games will demand will stress all parts of the current internet—servers as well as access lines. But, somebody will try it, and,—as noted earlier—interactivity is a big draw. The real appeal of network-based games, however, is multiple players., and if that can be supported, the response could be large.

Multi-user Interaction

Network games are a obvious application that could use a highly interactive, multiple user synchronous network transport service. There are also many business applications for this synchronous collaboration service, especially with the growing number of telecommuters. Synchronous collaboration is not video (or audio) conferencing alone, but multiple users simultaneously interacting through an application. Whiteboards, multi-user spreadsheets, CAD design, or distance learning are only a few of the possibilities. The network infrastructure support again needs low-latency and, in some cases, high reliability. Much like the internet telephony example, these are QoS characteristics that the standard internet will have difficulty providing, even with high-bandwidth access lines. The opportunity for the LECs is to find a way to sort these traffic types out from a combined user traffic stream and then transport them through the POTS circuit-switched network that is better suited to providing the needed QoS.

Scenario Descriptions and User Size Estimates

The previous discussion shows that there are many factors that will have an impact on the magnitude and nature of future Internet traffic. These factors will interact in unpredictable ways. One method of dealing with this unpredictability is to define a number of scenarios that account for all possible outcomes. The scenario analysis should represent each of the factors as an independent (but possibly correlated) dimension with a pessimistic and an optimistic outcome. However, for this study, we have chosen only two dimensions to represent the different outcomes of Internet traffic increase scenarios. While this is a oversimplification, it will illustrate the methodology and allow us to analyze the principal factors.

The four scenarios for optimistic/pessimistic assumptions about the growth of Internet traffic types are represented by the four quadrants shown in Figure 5 below (+ is optimistic growth and - is pessimistic growth).

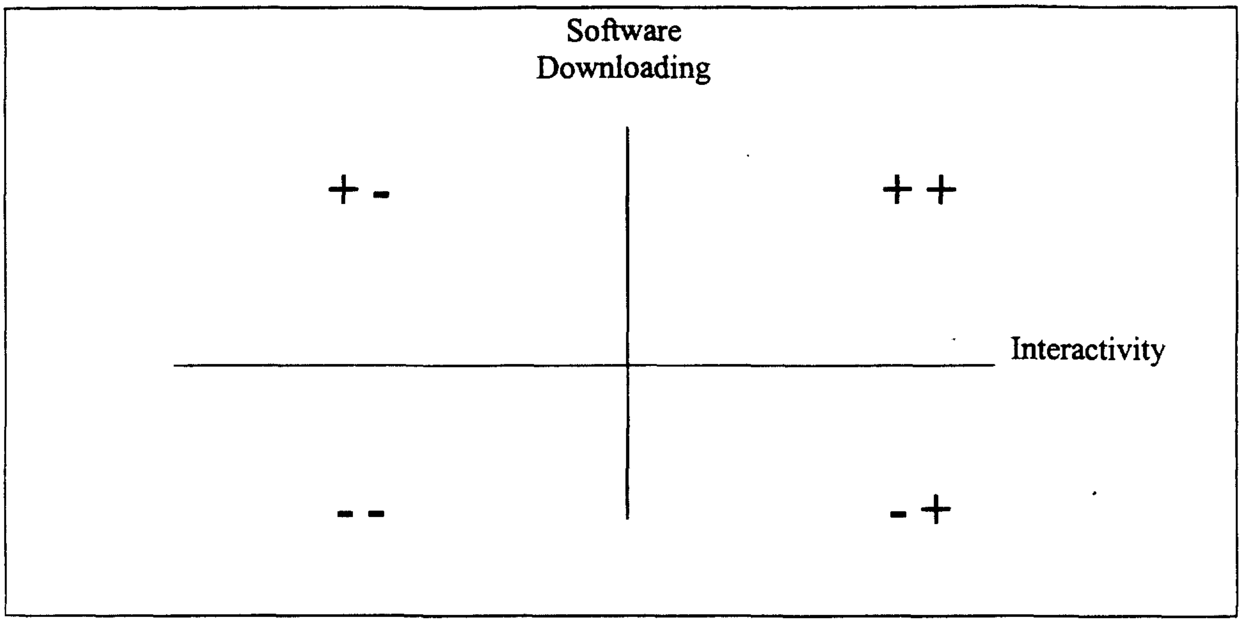

FIGURE 5: FOUR SCENARIOS

The four scenarios represent:

I) Most pessimistic—no big increases in download or interactive traffic:

- Business as usual
- Normal projections of the current active modem users and current mix of traffic types are the majority of future Intenret users

II) Low-latency interactive Takes off but NC/components does not

- Internet Telephony market really takes off. LECs must do something to protect their basic voice business
- Strong need for two-way low-latency access. There is a market opportunity for LECs. additional demand for voice network type service. they know how to do this. Need to get right pricing structure to make this a profitable venture

III) Downloading takes off, but Interactivity does not

- Internet telephony is a bust

- NCs are booming
- Cable modems and DBS become a real competitor
- LECs need some unique strategies (proxy servers at COs for most popular downloaded components)

IV) Most Optimistic—big increases in both download and interactive traffic:

- Large new NC market and lots of games
- Large user growth (NCs)
- New services (not many NCs but lots of games)
- More need for two-way low latency and high bandwidth access

Growth Projections

We have used data from the VALS studies that gives us VALS segment shift and penetration changes projected to the year 2002 (the only year for which such data was available) The growth estimates for the year 2000 and 2004 can be extrapolated from these numbers. Growth projections to the year 2002 are summarized for each of the VALS groups and teens from age 13 to 17 in Table 2 below have been modeled by assuming:

- The VALS projections are used for estimating the number of users under scenario I, the (conservative) predictable growth of active home internet users
- a 0.9% annual growth rate of the U.S. adult population over the next 5 years
- a ratio of active home users to all users of 65% by 2002 (up from 57% today)
- teens follow the VALS segments of their parents (we should state that this assumption is weak, since some of the VALS segments are age related. However, we only use this assumption to group teens into either scenario II or III, so the potential error from this assumption is reduced)
- possible scenarios under which larger penetrations can be expected are assigned to each VALS segment. (scenario IV includes all more optimistic penetrations)

Table 2 shows the projected numbers of active Internet home users for the year 2002. The breakout into scenarios follows the discussion of the areas of dissatisfaction of each VALS segment. Scenario I is the projection for normal growth of existing adult users with current traffic types. Scenario IV is the most optimistic projections for the new traffic types. The breakouts for Scenario II and III are:

- *Actualizers*—adults and teens would be actracted by new interactive services

- *Achievers*—adults will not change their usage based on either new interactive services or NC/component technologies, however teens will be attracted to new interactive services.
- *Fulfilleds*—adults will be attracted by new services enabled by component technologies. Teens will be attracted by new interactive services.
- *Strivers*—adults will not change their usage pattern based on either new interactive services or NC/component technologies. Teens will be attracted to new interactive services.
- *Experiencers*—adults and teens will be attracted to new interactive services.
- *Makers, Believers and Strugglers*—adults and teens will be more willing to use the Internet because of the lower-cost and level-of-expertise needed with NC/component technologies

Group	**Segment Population (Adult) 2002**	**Segment Population (Teens) 2002**	**Scenario I 2002**	**Scenario II 2002**	**Scenario III 2002**	**Scenario IV 2002**
Actualizers	27.93	2.94	9.08	12.33	9.08	12.33
Achievers	25.79	3.74	5.03	6.85	5.03	10.20
Fulfilleds	25.83	2.67	3.69	5.00	7.39	8.69
Strivers	27.95	3.21	2.91	4.16	2.91	4.16
Experiencers	23.62	3.47	2.92	5.96	2.92	5.96
Makers	23.62	3.21	2.15	2.15	3.14	3.14
Believers	30.12	4.54	1.37	1.57	1.80	1.80
Strugglers	21.50	2.67	0.06	0.06	0.17	0.17
Total	206.36	26.45	27.21	38.07	32.43	46.45

Table 2 - GROWTH PROJECTIONS

Figure 6 shows the projections graphically with linear interpolations for the years other than 2002. The interpretation is that Scenario I is the most conservative projection, assuming that only the current active home modem users will be the nucleus of the growth. Again, this is the predictable but conservative estimate. Scenario IV is the most optimistic projection and assumes that both interactive and software downloading applications take off. Scenario II is just the interactive services taking off. Since there is a lot of activity around internet voice, we expect this scenario to grow faster as the graph shows. Scenario III—software downloading—say, in support of Network Computers, will grow less rapidly because of all the supporting technologies that must be developed. These projections assumes the current price structure for home Internet access. The next section discusses demand for higher bandwidth access related to pricing.

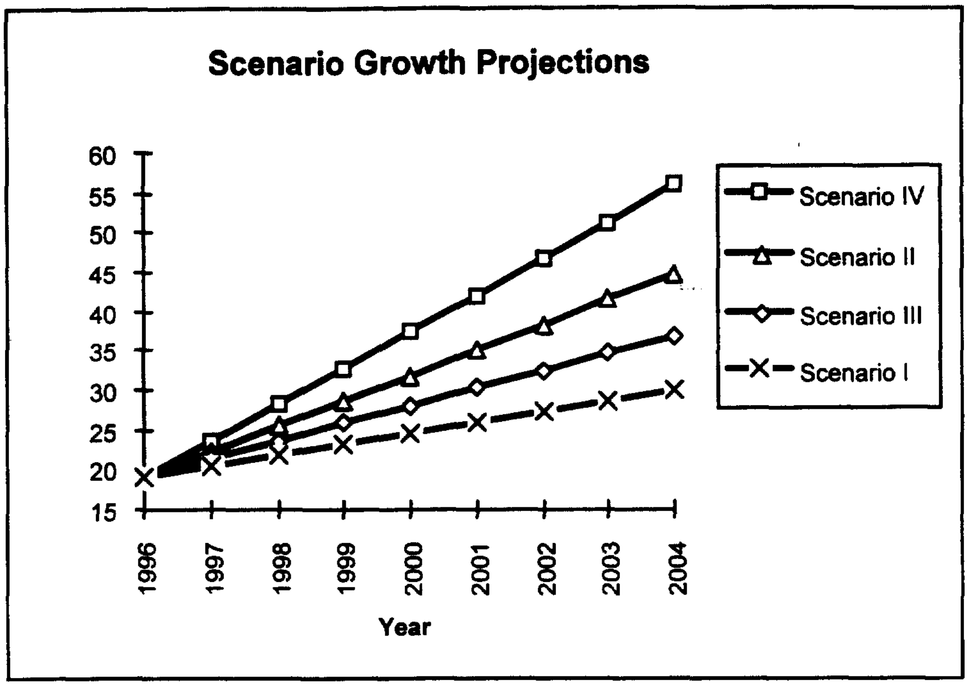

FIGURE 6. GROWTH PROJECTIONS FOR THE FOUR SCENARIOS

NATIONWIDE DEMAND CURVES FOR INTERNET ACCESS

Demand Curves for Internet Access

One of the objectives of this study is to develop quantitative estimates and forecasts—in the form of nationwide demand curves as a function of price and bit rate—for high-speed digital access, for 1998, 2001 and 2004. This section develops such estimates, focusing on Internet access and on the residential market segment. These preliminary results are offered with the understanding that they are necessarily speculative, given the rapidly evolving nature of the Internet.

There is not yet enough quantified information about the market for high bandwidth Internet access services to form the basis for an accurate demand model. The predictions shown in Figure 3 show the number of active users who access the Internet from home. This number is the upper bound of possible users that would convert to higher bandwidth access. Exactly what percentage would convert is uncertain. Likewise, it is not yet possible to develop demand curves of price vs. quantity to any level of detail beyond initial, rough estimates. The Internet is still relatively new, as is its use by the general population. In any case, market demand is growing and changing too rapidly to allow for an accurate snapshot of its detailed characteristics—especially its price sensitivity. Still, enough information is now available, primarily in the form of trial results and price points, to provide some useful, initial approximations.

Demand, Service Quality, and Line Speed

The demand function for Internet access will show price (P) inversely related to market penetration (Q). But price is not the only determinant of demand. Other factors that influence market acceptance include aspects of the service itself—e.g., its desirability, its usefulness, and its perceived quality. If there are several service variants that differ enough in these characteristics (e.g., one with very low quality and another with very high quality), they will be perceived as separate products, each with its own demand curve. Such a demand function can generate a whole family of demand curves.

Demand Curves and Service Quality

Figure 7 illustrates such a family of demand curves for Internet access as a function of "High", Medium" and "Low" service quality. Measures of service quality, as perceived by Internet users, include latency (e.g., delay in downloading a webpage) and consistency (continuity of Internet "dial tone—i.e., not being dropped during an online session). These demand curves merely reflect common sense by indicating that:

- At any level of market penetration (Q), people are willing to pay more for the higher quality.
- Alternatively, for any price (P), more market will be captured by a higher-quality product.

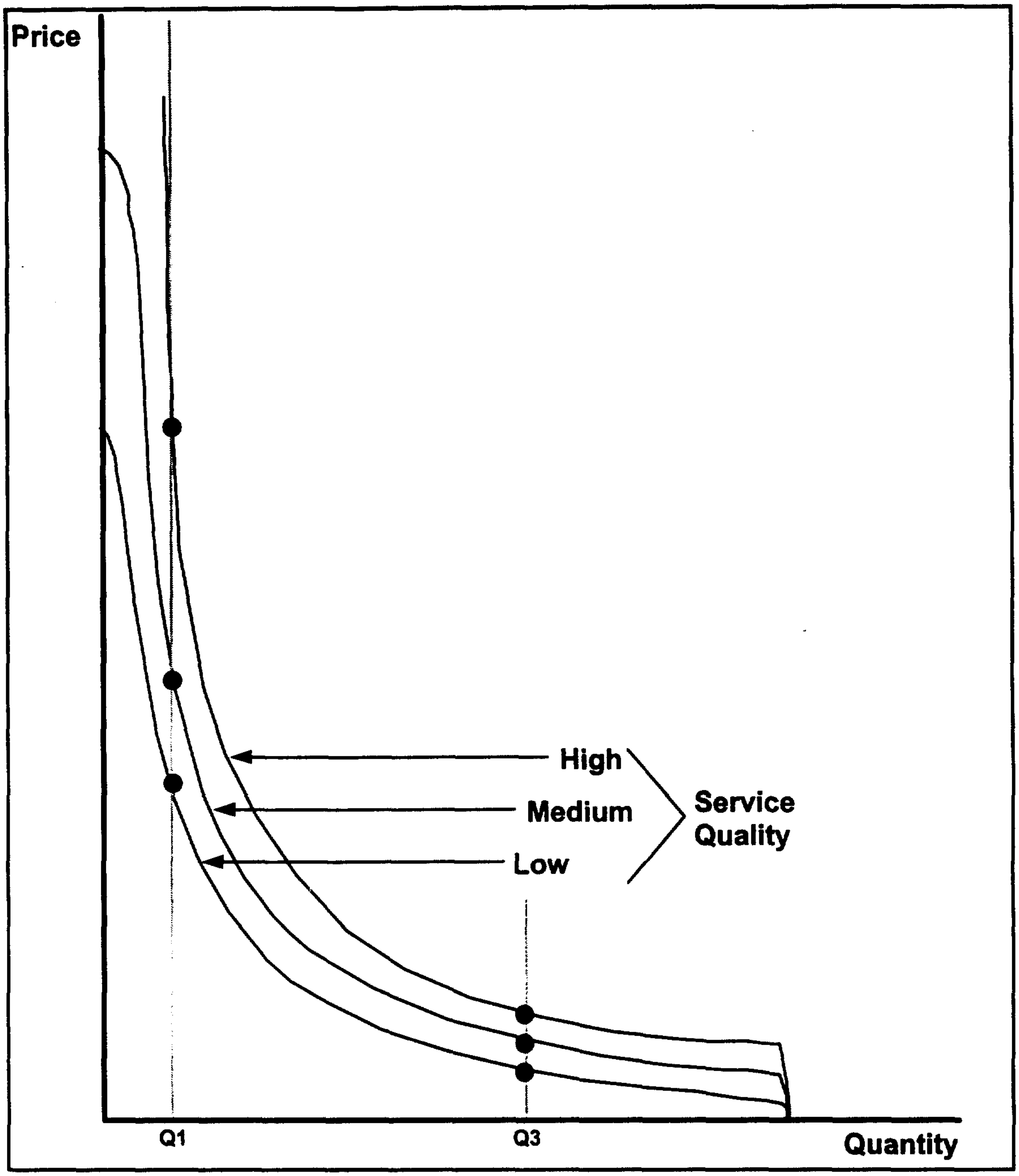

FIGURE 7: DEMAND CURVES AS A FUNCTION OF SERVICE QUALITY

Line Speed As a Derived Variable

Similar demand curve families are developed below as a function of access line speed. These should be interpreted with some caution, however, since access line speed is but one of many aspects of service quality, and a secondary aspect at that.

Market Segments and Price Points

Today, about 20 million adults in the U.S. are residential online users of the Internet. These users fall into three groups: telecommuters, home businesses, and general home users. These three segments and their respective contributions to market demand are depicted in Figure 8 as a function of access line speed. Note that the segments overlap in P-Q space as well—e.g., some consumers in Segment 1 are willing to pay less than others in Segment 2. The three line speeds illustrated are 56 kbps (representing the fastest dialup modems available today), 112-128 kbps (ISDN), and 1.1 Mbps (symmetric xDSL).

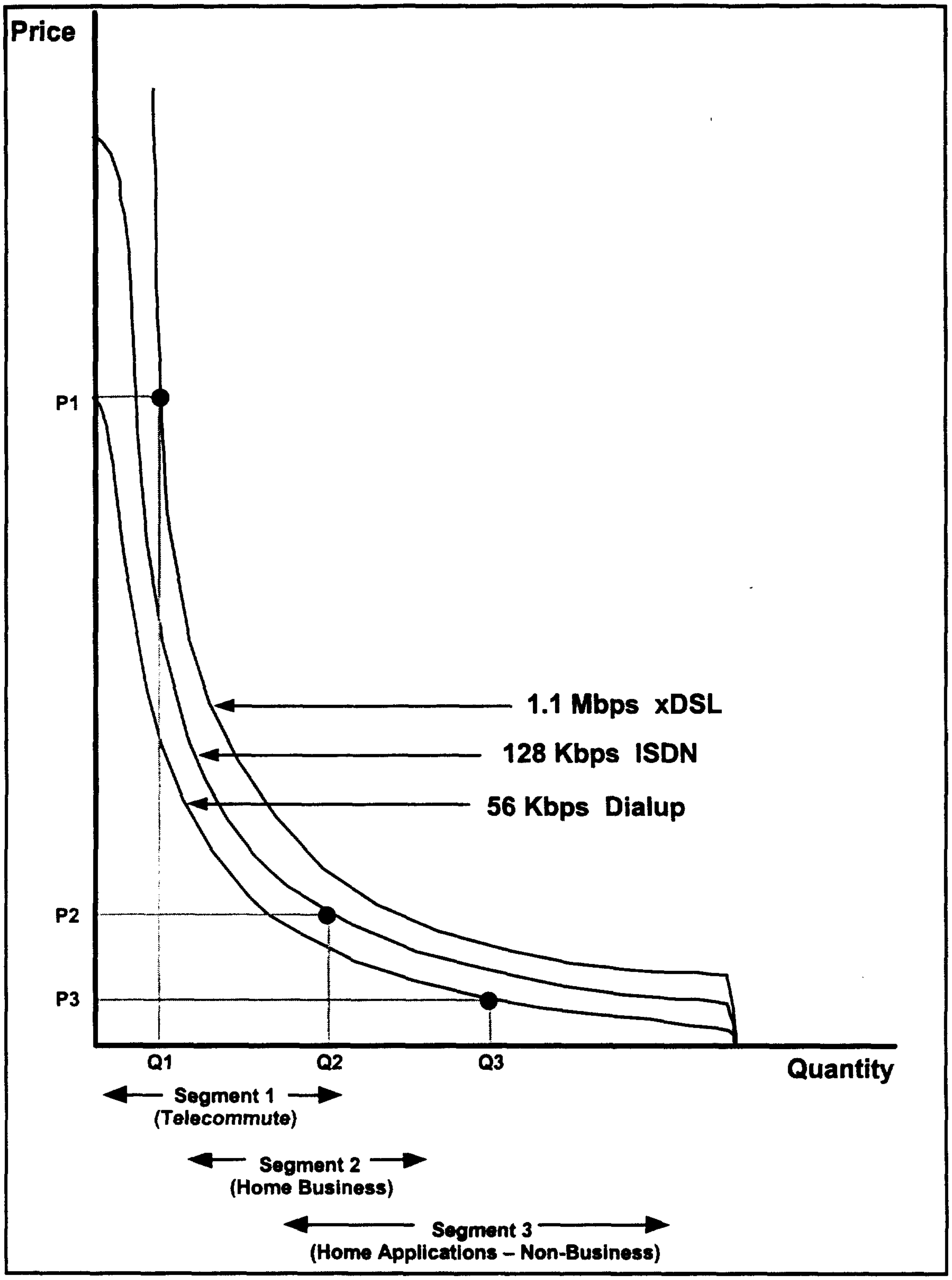

FIGURE 8: MARKET GROUPS AND PRICE POINTS.